



Aalborg Universitet

**AALBORG UNIVERSITY**  
DENMARK

## **Contributions to the model order reduction of large-scale dynamical systems**

Tahavori, Maryamsadat

*Publication date:*  
2013

*Document Version*  
Accepted author manuscript, peer reviewed version

[Link to publication from Aalborg University](#)

*Citation for published version (APA):*  
Tahavori, M. (2013). *Contributions to the model order reduction of large-scale dynamical systems*.

### **General rights**

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal -

### **Take down policy**

If you believe that this document breaches copyright please contact us at [vbn@aub.aau.dk](mailto:vbn@aub.aau.dk) providing details, and we will remove access to the work immediately and investigate your claim.

# Contributions to the model order reduction of large-scale dynamical systems

24 December, 2013

The accurate mathematical modeling of natural and man-made processes leads to models of high complexity. The simulation, analysis, control, design and implementation of the systems of high orders are difficult and costly if at all possible. To cope with these problems, suitable methods for model order reduction are required. Over the past few decades, there has been increasing interest in the methods which reduce the order of dynamical systems while preserving the input-output behavior and important features [1]-[3].

The model reduction techniques can be divided into two broad categories: singular value decomposition (SVD) based methods and the moment matching based techniques. The SVD-based methods have a guaranteed upper bound for the approximation error and they usually preserve the stability of the original model in the reduction process. The moment matching based methods are usually more efficient computationally, but they have no guaranteed error bound. The stability of the reduced order model is not guaranteed when these methods apply [1]-[3].

The balanced model reduction introduced in [4] is one of the most common model reduction schemes. To apply balanced truncation, the system is first represented in a basis where the states which are difficult to reach are simultaneously difficult to observe. This is achieved by simultaneously diagonalizing the controllability and the observability gramians, which are solutions to the controllability and the observability Lyapunov equations. Then, the reduced model is obtained by truncating the states which have this property. Balanced model reduction method is modified and developed from different viewpoints [1]-[12]. The time-interval balanced truncation is among the methods which improves the accuracy of the ordinary balanced truncation [5], [6], [10]. The frequency-interval balanced truncation is another well-known method which improves the accuracy of the ordinary balanced truncation [5], [7]-[9], [13]. In both classes of techniques which improve the accuracy of the ordinary balanced reduction gramian plays a key role. The gramians are matrices with the embedded controllability and observability information. The controllability and observability gramians were first introduced in [14] and [15] and more recently in [4]. It is well-known that the controllability gramian shows the level of controllability. Similarly, the observability gramian contains information of the level of observability for a system. Apart from the well-known

application of gramians in model reduction, they have been extended and have been used in applications such as control configuration selection [16]-[22].

## References:

1. C. Antoulas, Approximation of Large-Scale Dynamical Systems, Advances in Design and Control. Philadelphia: SIAM, 2005.
2. G. Obinata, and B. D. O. Anderson, Model Reduction for Control System Design. London: Springer-Verlag, 2001.
3. S. Gugercin, and A. C. Antoulas, A Survey of Model Reduction by Balanced Truncation and Some New Results, International Journal of Control, vol. 77, pp. 748-766, 2004.
4. B. C. Moore, Principal component analysis in linear systems: controllability, observability, and model reduction , IEEE Transactions on Automatic Control , pp. 17-32, AC-26, 1981.
5. W. Gawronski, and J.-N. Juang , Model Reduction in Limited Time and Frequency Intervals , International Journal of System Sciences , vol. 21, no. 2, pp. 349-376, 1990.
6. M. Tahavori and H. R. Shaker, Model reduction via time-interval balanced stochastic truncation for linear time invariant systems. , International Journal of Systems Science, vol. 44, no. 3, pp. 493-501, 2013.
7. H. R. Shaker, and R. Wisniewski , Model reduction of switched systems based on switching generalized gramians, International Journal of Innovative Computing, Information and Control, vol. 8, no. 7(B),2012.
8. H. R. Shaker, and R. Wisniewski, Switched systems reduction framework based on convex combination of generalized gramians, Journal of Control Science and Engineering, 2009.
9. H. R. Shaker and R. Wisniewski, Generalized gramian framework for model/controller order reduction of switched systems, International Journal of Systems Science, vol.42, no.8, pp.1277-1291, 2011.
10. H. R. Shaker, and M. Tahavori, Time-Interval Model Reduction of Bilinear Systems, International Journal of Control, 2013.
11. M. Tahavori and H. R. Shaker, Relative error model reduction via time-weighted balanced stochastic singular perturbation , Journal of Systems Science , Journal of Vibration and Control, vol. 18, no.13, pp. 2006-2016, 2012.
12. M. Tahavori and H. R. Shaker, Time-weighted balanced stochastic model reduction, 50th IEEE Conference on Decision and Control and European Control Conference (CDC-ECC), pp. 7777-7781, 2011.
13. H. R. Shaker, and M. Tahavori, Frequency-Interval Model Reduction of Bilinear Systems, IEEE Transactions on Automatic Control, will appear in July issue, 2014.
14. E. G. Lee and L. Marcus, Foundations of Optimal Control Theory, New York, Wiley, 1967.
15. R W. Brockett, Finite Dimensional Linear System, New York. Wiley, (1970).
16. H. R. Shaker, F. Shaker, Control Configuration Selection for Linear Stochastic Systems, Journal of Process Control, Vol. 24, Issue 1, pp. 146–151, 2014.
17. H. R. Shaker, M. Tahavori , Frequency-Interval Control Configuration Selection for Multivariable Bilinear Systems, Journal of Process Control, Vol. 23, No. 6, 2013, pp. 894-904, 2013.
18. H. R. Shaker and Jakob Stoustrup, An interaction measure for control configuration selection for multivariable bilinear systems, Nonlinear Dynamics, vol. 72, no. 1, 2013, pp. 165-174, 2013.
19. H. R. Shaker and M. Komareji , Control Configuration Selection for MIMO Nonlinear Systems, Industrial & Engineering Chemistry Research, 51(25), pp. 8583-8587, 2012.
20. H. R. Shaker and M. Tahavori, Optimal Sensor and Actuator Location for Unstable Systems, Journal of Vibration and Control, vol. 19, no. 12, pp. 1915-1920, 2012.
21. H. R. Shaker, and Jakob Stoustrup, Control Configuration Selection for Multivariable Descriptor Systems, Proceedings of American control conference, Canada, 2012
22. H. R. Shaker , M. Tahavori Control Reconfigurability of Bilinear Hydraulic Drive Systems, Proceedings of IEEE Conference on Fluid Power and Mechatronics, Beijing, China, 2011.